# Visualization of Sensor Network Coverage with Sensor Location Uncertainty

Tim Sodergren and Jessica Lohse

May 1, 2017

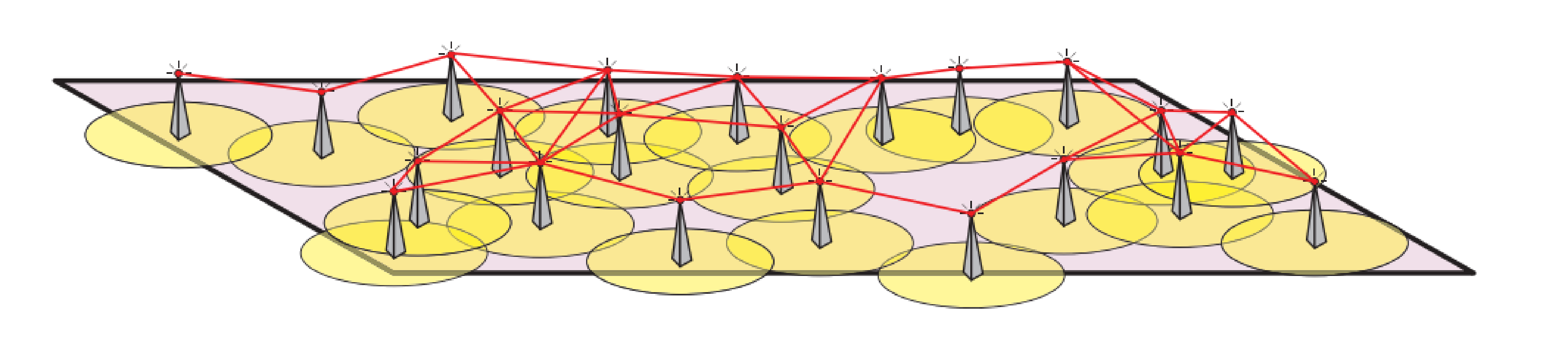
CS 6170 – Computational Topology

# outline

- Motivation – Wireless Sensor Networks
  - Location Uncertainty
- Problem Statement and Objective
- Technical details – Computing Simplicial Complexes
- Visualization overview and demonstration
- Conclusions

# Motivation - background

- Wireless Sensor Networks – spatially distributed, autonomous sensors to monitor physical or environmental conditions.
- Applications: Robotics, cellular phone networks, robotics, security and surveillance.



# Uncertain Data

- Often desirable to have low-cost hardware which leads to network nodes with limited localization capability, leading to uncertain node location data. Each nodes location may only be described by a probability distribution.

# Problem Setup

We consider a restrictive case referred to as “indecisive data”.

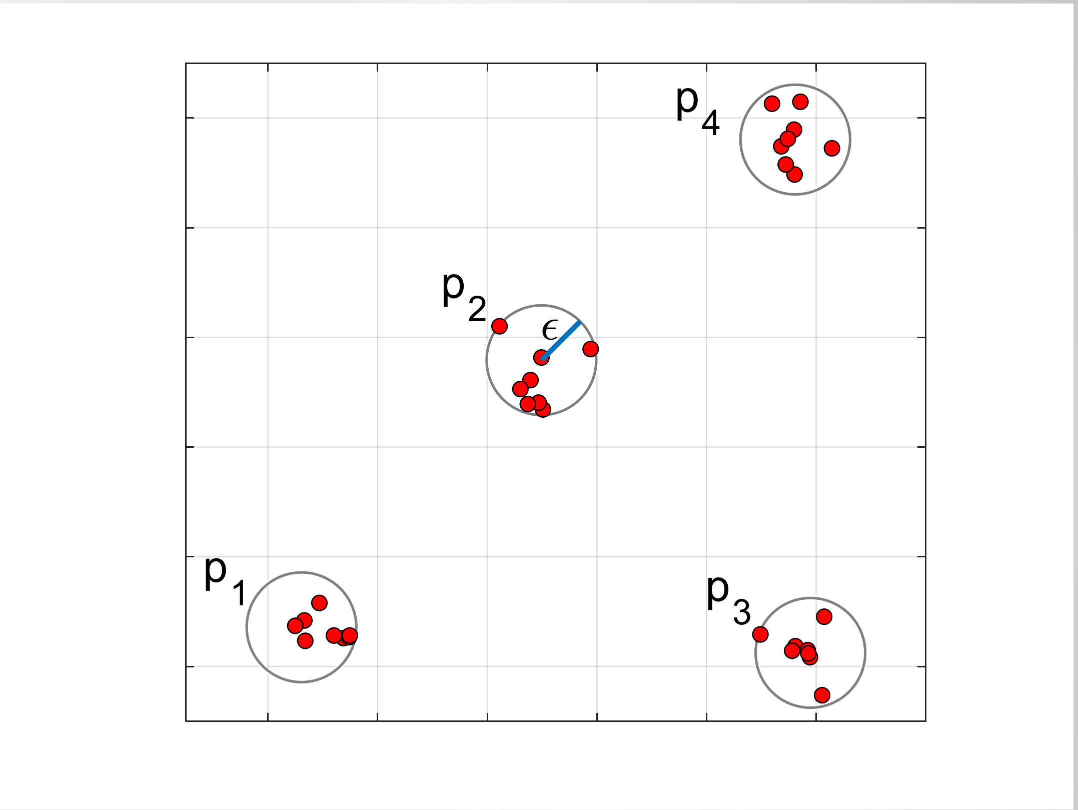
For a set of *n* sensors, P in Euclidean space:

$$P = \{p_1, p_2, \ldots, p_n\}$$

Each uncertain point, *Pi* has exactly k possible locations:

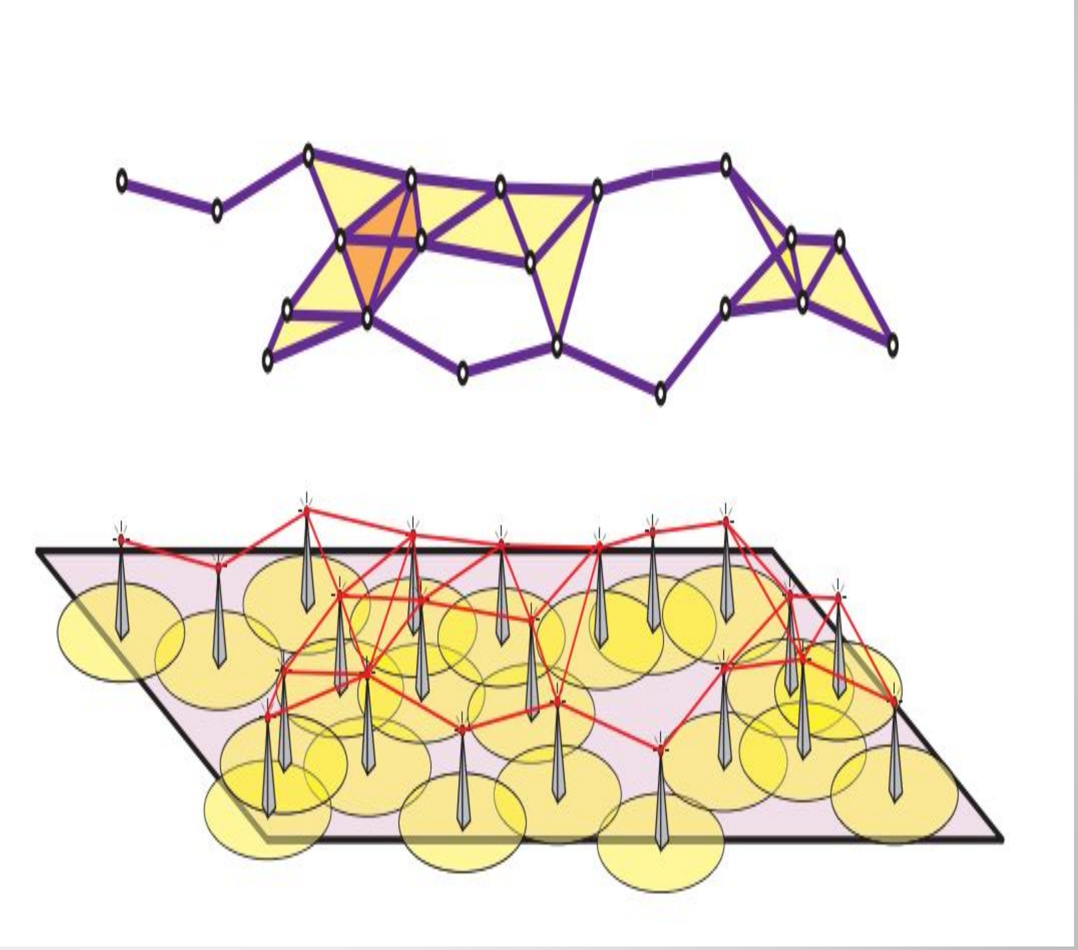
$$p_i \in \{p_{i1}, p_{i2}, \ldots, p_{ik}\}$$

These possible locations exist within a “radius of uncertainty”, ε, with each location having an equal probability of *1/k.*



## Objective:

To compute and visualize the simplicial complexes of uncertain sensor network coverage, determining the probability of each simplex.

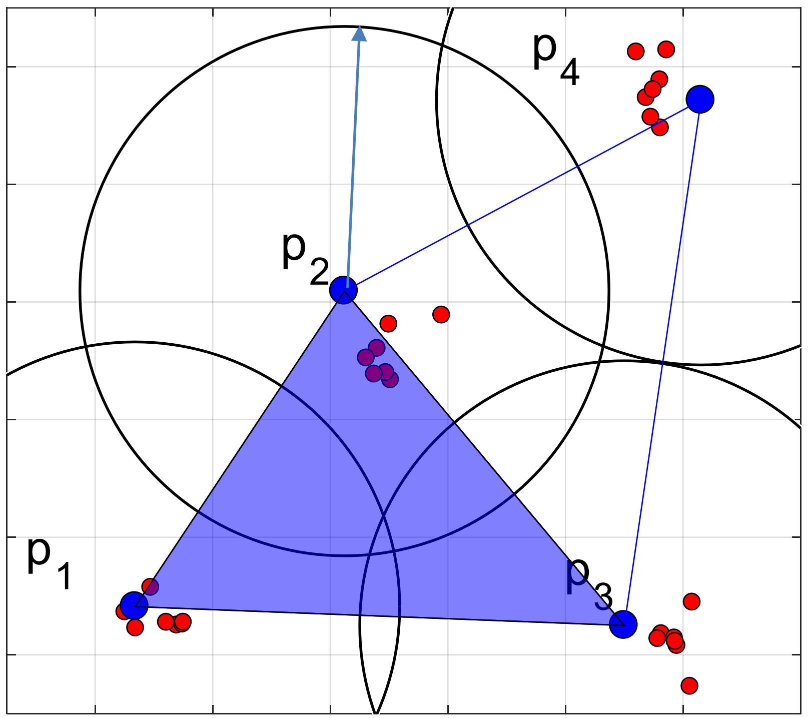


# Related Work

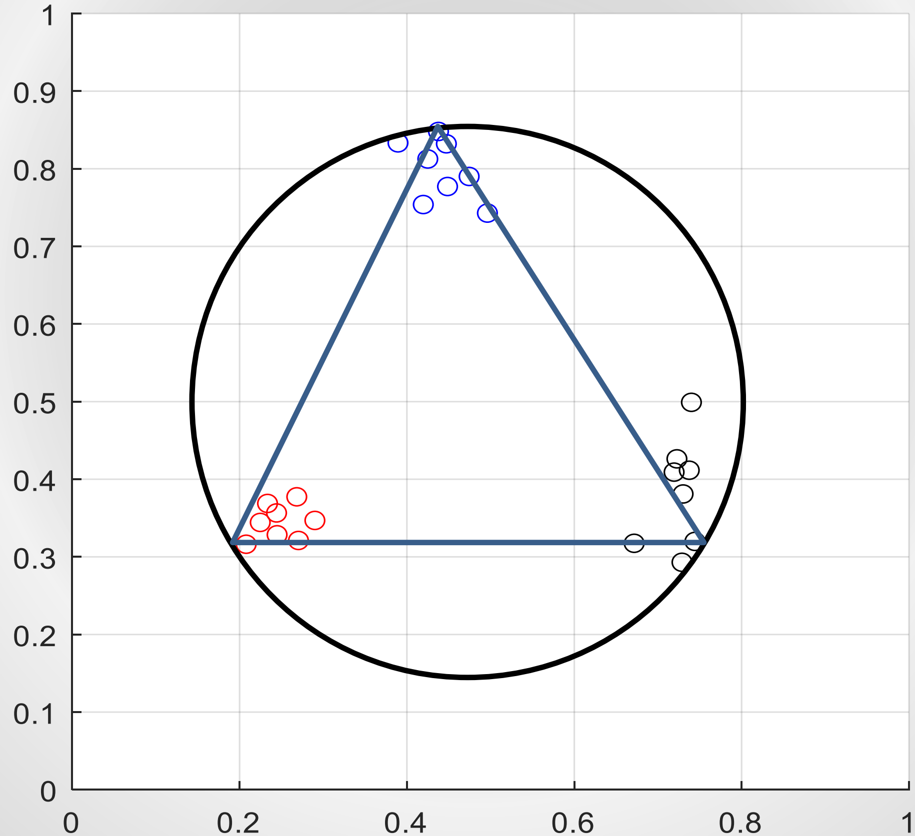

- V. De Silva and R. Ghrist. Homological sensor networks. *Notices Amer. Math. Soc*, pages 10-17, 2007.
- C. Schulz, A. Nocaj, J. Goertler, O. Deussen, U. Brandes, and D. Weiskopf. Probabilistic graph layout for uncertain network visualization. *IEEE Transactions on Visualization and Computer Graphics*, 23(1):531-540, Jan 2017.
- Jorgensen, Allan, Maarten Löffler, and Jeff M. Phillips. "Geometric computations on indecisive and uncertain points." *arXiv preprint arXiv:1205.0273* (2012).
- Sodergren, Tim,Visualization class project, Fall 2016

# Calculating probability of each simplex

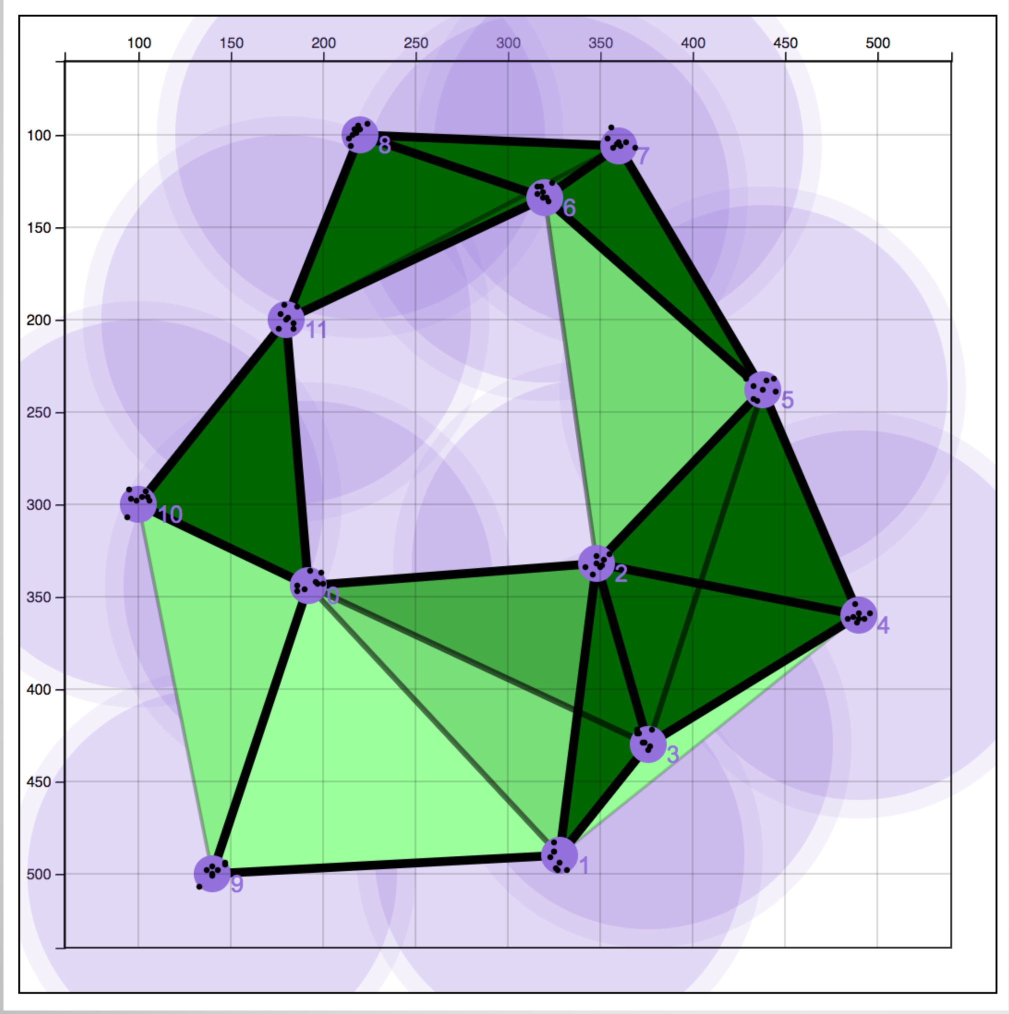
- We define an “instance” as one possible realization of sensor locations.
- There are $k^n$ possible instances.
- Each sensor has a sensing radius, *rc.*
- An edge has a probability of existing between 2 sensors if their coverage radii overlap.
- In the Cech complex a face or triangle exists between three points if their coverage radii share a common intersection.
- The Vietoris-Rips complex requires only that all three vertices are pairwise connected.

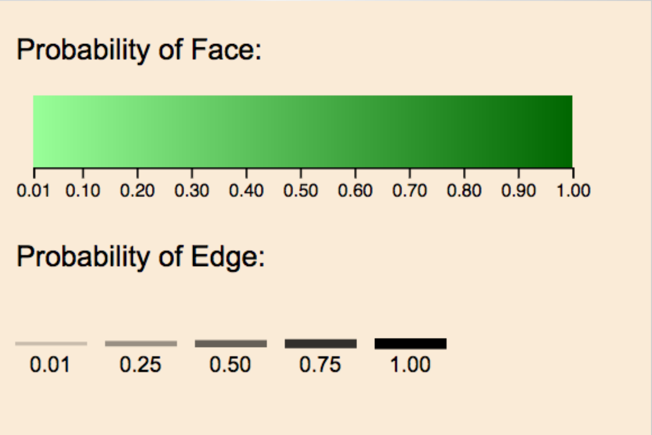


# Computing probability – Minimum Enclosing Disk

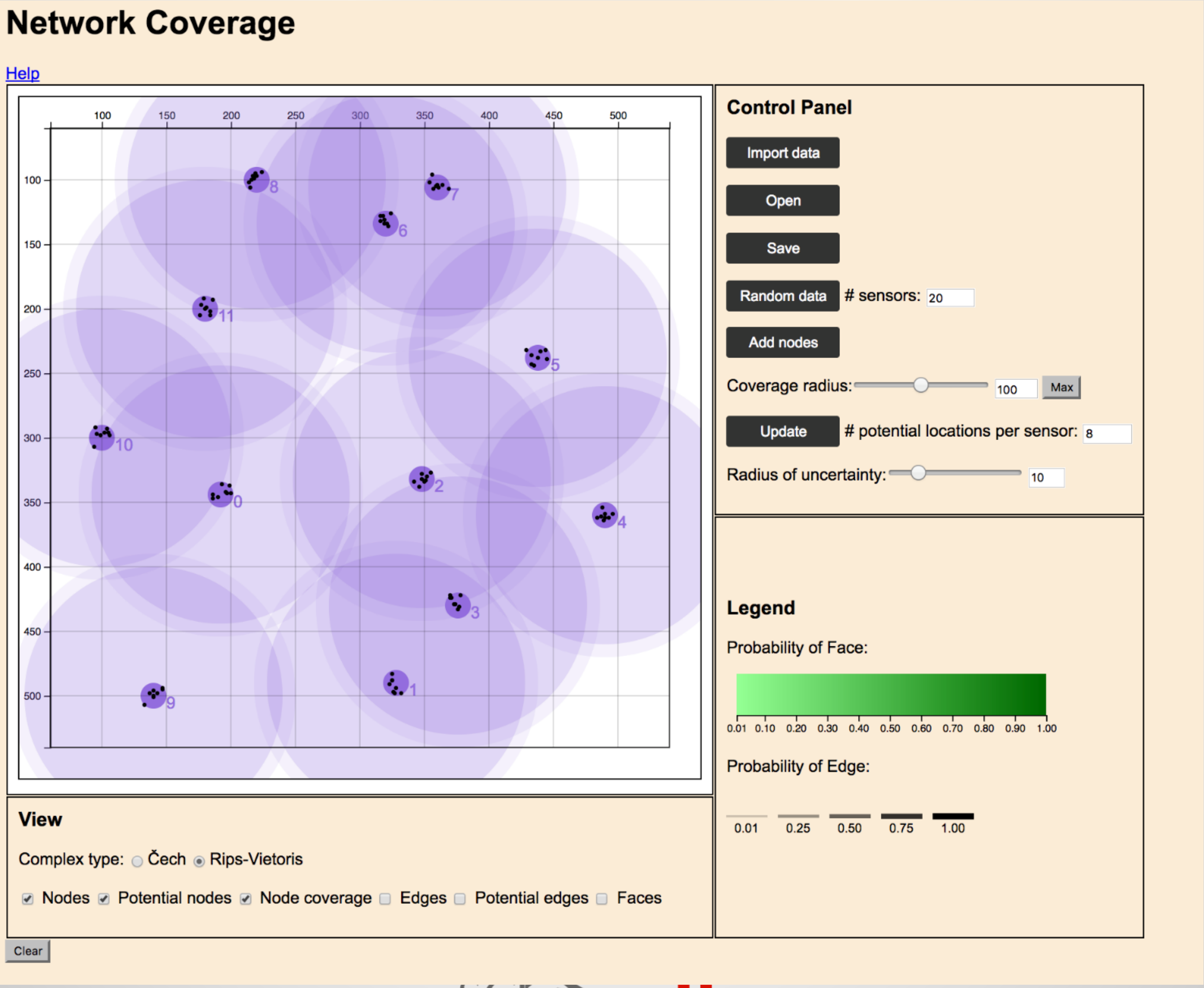


# Visualization Details



# Results



Network Coverage
Help
Control Panel
Import data
Open
Save
Random data
# sensors: 20
Add nodes
Coverage radius: 100 Max
Update
# potential locations per sensor: 8
Radius of uncertainty: 10
Legend
Probability of Face:
0.01 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Probability of Edge:
0.01 0.25 0.50 0.75 1.00
View
Complex type: Čech Rips-Vietoris
Nodes Potential nodes Node coverage Edges Potential edges Faces
Clear

# Conclusions

- Wireless Sensor Networks are an increasingly significant component of the modern computing environment.
- Determing coverage when sensor locations are uncertain poses additional challenges.
- We can address this via TDA by computing probabilistic simplicial complexes for input into coverage models (i.e. persistent homology).
- We have developed means of also visualizing these types of networks.

# Future work

- Taking output to external TDA package for determination of coverage via persistent homology.
- Generalizing solution to allow for probability distributions of sensor locations.
- Improved rendering for scalability.

# Contributions

- Implemented a simple algorithim for determining the "Probabilistic Simplicial Complex" of an uncertain WSN.
- Developed a in interactive visualization tool that allows for the setup and manipulation of an uncertain WSN and computation and output of probabilistic simplicial complexes.
- Individual contributions:
  - TS – algorithm development – computation of simplicial complexes
  - JL – visualization design, rendering of probabilistic complexes

# Questions